IC	9076

Bureau of Mines Information Circular/1986

Coal Mine Roof Instability: Categories and Causes

By Noel N. Moebs and Raymond M. Stateham

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
Donald Paul Hodel, Secretary

BUREAU OF MINES
Robert C. Horton, Director

Library of Congress Cataloging in Publication Data:

Moebs, Noel N
Coal mine roof instability.

(Bureau of Mines information circular ; 9076)

Bibliography: p. 12.

Supt. of Docs. no.: I 28.27: 9076.

1. Coal mines and mining—Safety measures. 2. Mine roof control. 3. Coal—Geology. I. Stateham, Raymond M. II. Title. III. Series: Information circular (United States. Bureau of Mines) ; 9076.

~~TN295.U4~~ 622s [622'.334] 86-600014

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°	degree	MN/m^2	meganewton per square meter
in	inch	psi	pound (force) per square inch

COAL MINE ROOF INSTABILITY: CATEGORIES AND CAUSES

By Noel N. Moebs [1] and Raymond M. Stateham [2]

ABSTRACT

Coal mine roof failure is categorized according to character, trend, or pattern of occurrence. Two principal categories of failure are proposed--geology related and stress related. Geology-related failure includes both lithology and structure. Each of several subcategories reflects the probable cause of failure and thereby provides a basis for the selection of appropriate techniques for reducing the incidence of failure. These control techniques, depending on local conditions, may include supplementary support, destressing, reduction of mine air humidity, or a change in the customary support methods.

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INTRODUCTION

Roof-bolting practices are largely empirical, having evolved from much experimentation and trial and error. Bolting theory still is more descriptive than mathematical. The subsurface environment surrounding a coal mine is complex, and the failure of bolted mine roof is difficult to describe fully. Nonetheless, the qualitative identification of the conditions leading to roof failure can provide some basis for modification of mine design that should reduce instances of failure under prevailing conditions. Most operators are aware of the sometimes subtle and sometimes pronounced changes in roof conditions that occur during a mining operation, and the difficulty of either predicting these changes or responding with the appropriate support or mine design to prevent roof failure. However, the recognition of a general characteristic of individual falls or a pattern of multiple falls usually will offer some clue as to the cause and, therefore, the appropriate remedial action.

The purpose of this paper is to provide the mine operator with a guide for determining the probable cause of persistent roof failure based on the occurrence, character, and distribution of the individual falls in a mine, and to offer suggestions as to how additional roof failure might be avoided. The diagnosis of roof failure is based chiefly on the careful examination of a mine roof-fall map, and recognition of certain characteristic patterns of distribution or modes of failure. This requires diligent documentation of a significant number of falls, as occasional widely distributed falls seldom are sufficient for analysis and in most mines would not indicate a need for action. Occasional failure can result from faulty materials or improper bolt installation, but these factors are outside the scope of this paper. Roof-fall documentation at the mine should include the following:

1. A mine map showing all roof falls and indicating not only the location, but also the approximate size and dimensions of the falls. This map will then provide information for determining trends of roof failure.
2. A mine map with surface topography superimposed for correlating roof fall occurrences to topography features.
3. A map showing positions of superjacent or subjacent mining.
4. A map showing roof structures such as clastic dikes or sandbodies, as well as major geologic features (faults, dense jointing, etc.). The combined information from maps of this type can be extremely useful in the diagnosis and prevention of roof failure.

The significance of roof-fall patterns became discernible upon an examination of numerous roof falls in scores of coal mines, followed by a review of supplementary geologic information on each property and an interview with underground personnel. Some patterns of roof falls were erratic or difficult to explain, and some were found to correlate with a transition in bolt type, mining cycle, or entry design. This paper summarizes the significance of roof-fall patterns attributable to structural or stress conditions and offers suggestions for remedial action.

Before describing roof-fall patterns and their significance, it must be emphasized that any supplementary information, such as maps showing the character and thickness of roof strata, or discrete roof structures such as rolls or clay veins, may help explain the occurrence of falls and aid in determining the appropriate remedial action.

The improper installation of bolts contributes to roof failure but, with respect to stress and geologic factors, is a lesser influence on roof-fall occurrence. There are several reasons for this condition. First, improperly installed, mechanically anchored bolts can be detected prior to failure by torque measurements; poorly installed full-column, resin-grouted bolts are not so easily detected. However, even these improperly installed bolts tend to be relatively effective support devices because some portion of the bolt's length is usually well bonded to the rock. As little

as 12 to 18 in of bond can provide an anchor that will hold a load greater than the yield strength of the steel bolt. On the basis of personal observations and experience, the authors believe improper installation is a lesser problem when compared to the stress and geologic influences discussed in this paper. This is especially true in coal mines because of the following:

1. Coal mines are located in relatively weak, bedded sediments where adverse stress and geologic conditions severely affect ground stability.

2. Coal mines generally use rotary drilling equipment that provides consistent hole sizes and spin rates so that the grout is mixed adequately for proper bolt installation.

3. Mechanical bolts are tested according to procedures defined by safety regulations.

Aside from inappropriate support, improper installation, configuration or size, or mining sequence for existing conditions, most roof failures can be attributed either to high stresses or to geologic defects in roof structures.

PREVIOUS WORK

Several schemes for classifying mine roof have been attempted, chiefly for the purpose of predicting the occurrence of roof falls from a knowledge of local geologic features. For example, Weir (1)[3] described six kinds of roof falls as follows: shale dusting or slaking, sandstone rolls, concretions, slabbing, clay seams, and massive. These categories of falls probably predominate in the specific area of Indiana studied but are of limited usefulness for the entire region. Hylbert (2) proposed a classification of roof falls based on the structural and compositional character or roof at a mine in eastern Kentucky. This scheme proved useful in projecting trends of roof condition as an aid in anticipating problem areas in advance of mining. Some inferences can be drawn from this scheme regarding the appropriate support method for each of the four types of roof conditions described by Hylbert.

Patrick and Aughenbaugh (3) have devised a classification based only on the geometry of a roof fall. The categories are dome, arch, minor, and sloughing. This simplified scheme is intended to expedite the reporting of roof falls independent of local conditions and to serve as a first step toward developing a means of predicting the occurrence and extent of future falls. While some inferences as to the cause of failure can be drawn from a geometric classification only, further usefulness in analyzing roof control problems is very limited.

The classification of roof proposed by the Bureau of Mines requires somewhat more information than that needed in the works of other investigators (3); however, it should provide for broader usage, supply a sound basis for diagnosing the underlying causes of roof failure, and indicate some appropriate means of reducing the rate of failure.

Often, a simple inventory of individual roof-fall occurrences will indicate the probable cause of failure, as shown in table 1, which is based on examples from four selected mines in western Pennsylvania and northern West Virginia. This method, however, requires extensive mapping of roof falls and is too broad in classifying, although it may be useful in conjunction with the classification scheme proposed here.

CATEGORIES OF ROOF FAILURES

For simplicity and clarity, the illustrations used here to designate various types of roof-fall patterns are schematic. Often the cause of roof failure is obscure and cannot be determined with any degree of certainty, or only through prolonged and sophisticated research. The following categories are intended only to provide mine operators and/or

[3] Underlined numbers in parentheses refer to items in the list of references preceding the appendix at the end of this report.

TABLE 1. - Tabulation of roof-fall occurrences

Mine	At inter-sections	Between inter-sections	At minor structures	>1 pillar length	Total	Principal cause of failure and support required
1:						
Number	163	23	4	10	200	Low-strength roof rock, requiring bolted headers, straps, and trusses.
Pct...	82	11	2	5	100	
2:						
Number	4	10	0	115	129	High lateral stresses (cutter roof), requiring posts and crossbars.
Pct...	3	8	0	89	100	
3:						
Number	21	12	0	350	383	High lateral stresses (cutter roof), requiring posts, crossbars, and steel sets.
Pct...	5	3	0	92	100	
4:						
Number	10	0	34	0	44	Minor structures, chiefly clay veins, requiring straps or header block.
Pct...	23	0	77	0	100	

mine safety personnel with the means to make a preliminary and rapid assessment of roof problems using observable patterns of roof failure and geologic information. While underground options always are limited, some early remedial measures might be attempted once the probable cause of failure has been established. Some of these measures are suggested. All roof-fall patterns have been divided into either of two categories--Type S or stress related, and Type G or geology related--and a schematic illustration of each subtype is provided for quick reference. Type G includes both lithology and structure-related failure to facilitate classification. Caution must be exercised in using only the illustrations since the accompanying description of related surface or subsurface features may be equally diagnostic.

TYPE S--STRESS RELATED

Subtype S_1, In Situ Stress

In the northern Appalachian coal region, one of the most common and easily recognized types of roof failures occurs beneath narrow stream valleys in areas of high relief (fig. 1). It is referred to by various miners' terms such as "pressure falls," "snap top," and "cutter roof." These falls can be recognized by comparing their occurrence with a map showing surface stream valleys where topographic relief is at least 100 ft. It has been estimated by several operators that when mining beneath or near such stream valleys, severe roof-fall problems will develop 90 pct of the time.

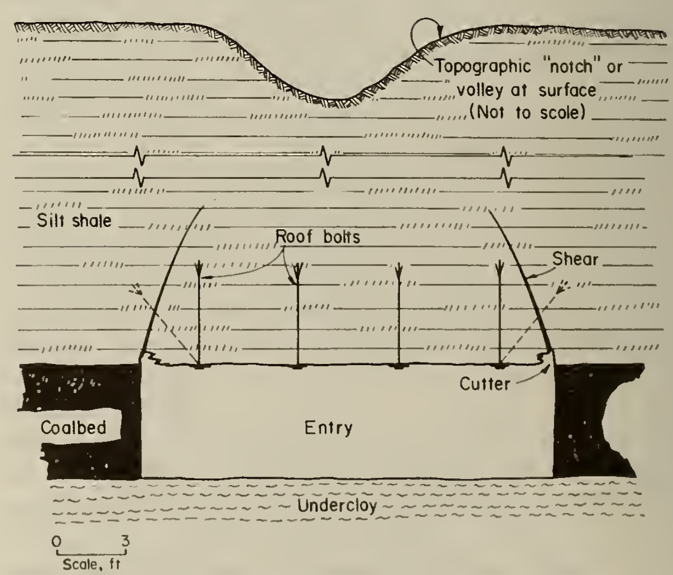

FIGURE 1. - Subtype S_1 roof failure associated with topographic "notch."

Examination of these falls shows little if any evidence that jointing contributed to the failure, and even the most competent roof rock is subject to this type of failure. The falls frequently result from a concentration of high lateral compressive stresses, a phenomenon described by several authors (4-8). They are recognized underground sometimes by an audible snapping sound immediately after mining, or by the development of a steeply dipping shear or "cutter" at the intersection of rib and roof within a few hours to a week or two after mining. This type of failure usually develops between intersections but may progress along cutters across one or more intersections for perhaps several hundred feet.

In some instances of S_1 roof failure, further falls have been prevented by the installation of supplementary angle bolts to intersect the cutter plane and anchor above the pillar (fig. 1). Currently, angle bolting is being tested in at least three mines for this purpose. The immediate installation of support to prevent any yielding of roof is commonly recommended. More severe S_1 failure will require posts and crossbars or possibly roof trusses. It may be virtually uncontrollable with crushing of posts or cribs leading to massive high roof falls.

Roof failure that clearly is caused by high lateral compressive stress, but that is not limited to occurrences beneath valleys and occurs somewhat randomly, is included here (fig. 2). It is characterized by the development of a cutter along the rib line within a few weeks of mining, roof cracks, and a typically sudden roof fall if not well supported. Kripakov (9) describes cutter roof failure in detail, discusses current control methods, and suggests some new alternatives. Competent shale roof fails under these pressures as readily as does softer laminated roof rock. The pattern of these falls commonly shows a preferred north-south trend in several of the U.S. coal regions. Blevins (4) reported a similar north-south failure condition in the Illinois coal basin. The falls

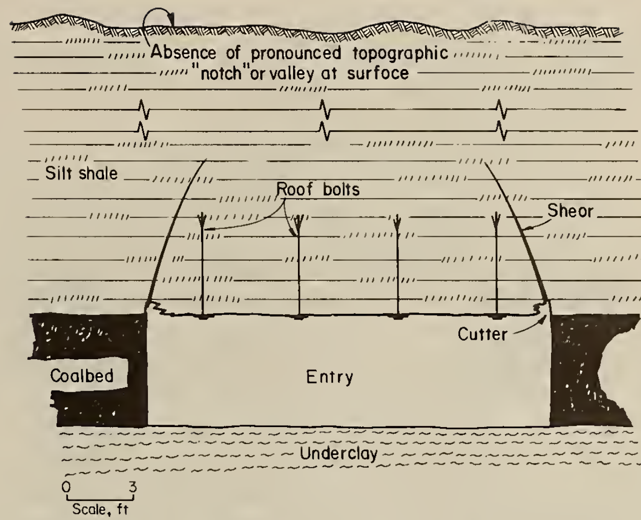

FIGURE 2. - Subtype S_1 roof failure attributed to high lateral regional stress.

generally begin between intersections and may zigzag around pillars to follow a north-south trend, or may show no clear directional preference. Subtype S_1 falls can be distinguished from those attributed to pillar punching by the absence of accompanying floor heave and pillar spalling, and by the evidence of a directional trend.

S_1 roof failure includes roof falls that tend to occur chiefly at the boundaries of multiple-entry mains. These falls typically begin as a cutter along the rib line and commonly have been attributed to "abutment pressures." The exact cause, however, remains disputable. When adequate pillar support is provided and there is no evidence of roof deflection in the central zone, the pressure arch theory does not seem to offer an adequate explanation of failure, and in situ stresses are suspected. A change in entry orientation, where possible, has proved to be more beneficial than a modification of pillar design, but experience in controlling this problem is very limited. Destressing of the rock surrounding an entry by means of roof or rib slotting or induced caving of an adjacent entry has been attempted with varying degrees of success. Destressing, however, while sound in theory, is risky, and requires equipment not always available

in a mine. Normally, supplementary support as described in S_1 failure is suggested.

Subtype S_2, Induced Stress

Induced-stress roof failure (S_2--figure 3) nearly always can be related to superjacent or subjacent second mining or to a squeeze or pressure override from a panel that has not fully caved. The map overlay technique, such as that described by Ellenberger (10), will detect the effects of multiseam mining on entry stability, while pressure overrides nearly always occur within a few hundred feet of adjacent pillar extraction or pillar stumping. Geologic and mining correlations are useful in resolving the problem of induced stresses, especially with respect to the massive character of strata that transfer overburden weight onto pillars or abutments. Induced stresses from multiseam mining or pressure overrides lead to various combinations of floor heave, pillar spalling or deformation, pillar punching into floor and roof, and cutter roof, with the actual failure of roof sometimes occurring late in the sequence of events.

The remedy for S_2 roof failure due to pressure overrides probably lies with improved pillar extraction and caving or with oversized pillars. Ground control problems resulting from multiseam mining may be alleviated by following extraction sequencing guidelines as described by Britton (11). An increase in conventional bolting, strapping, or posting seldom is of much value in preventing further failure, therefore steel sets generally are needed.

TYPE G--GEOLOGIC DEFECTS

Categories of roof failure attributed to geologic defects or geologic character of rock are divided into five subtypes, as follows:

- G_1 - Low rock strength.
- G_2 - Water sensitivity.
- G_3 - Bedding-plane spacing.
- G_4 - Minor structures.
- G_5 - Major structures.

Subtype G_1, Low Rock Strength

This category of roof includes all roof rock that is relatively soft, usually poorly laminated, and low in RQD (Rock Quality Designation), point load, and compressive strength. The physical properties for subtype G_1 (fig. 4) commonly would fall below the following values:

Point load index........	0.3 MN/m^2
Shore hardness..........	20
Compressive strength....	2,500 psi

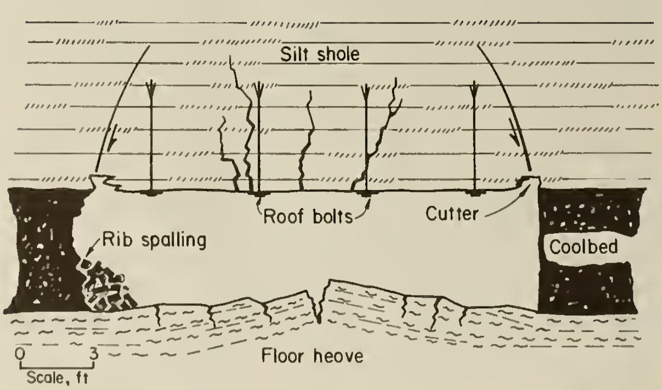

FIGURE 3. - Subtype S_2 roof failure attributed to mining-induced stress.

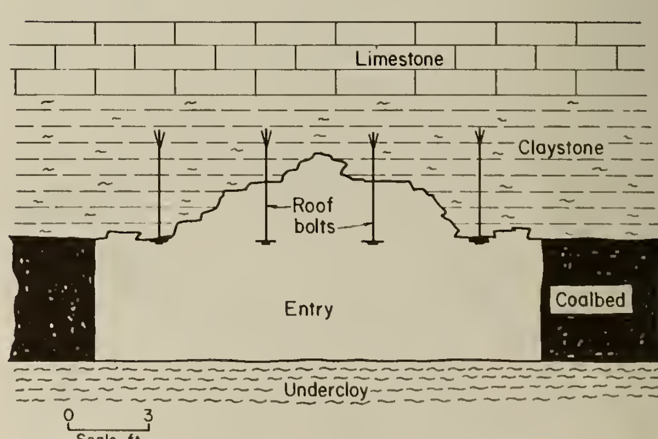

FIGURE 4. - Subtype G_1 roof failure attributed to low rock strength.

Low-strength rocks include most claystone (especially the "drawslate" that overlies the coalbed) and underclay or seat earth. These rocks generally are not self-supporting for normal entry widths, tend to fall from the roof soon after the supporting coal has been removed, and therefore must be supported as quickly as possible after exposure. Bolted headers or straps usually are needed, and trusses are useful in severe cases, where the deadweight of collapsing roof is not excessive; otherwise, posts and crossbars become necessary. Full-column resin-grouted and tensioned resin-anchored bolts have been used successfully at some localities to support this type of roof, but further assessment is needed. With most mechanical bolts, there is a problem of tension bleedoff in soft rock due to anchor slippage; in addition, segments of soft rock tend to fall from between bolts, and the reinforced beam effect of the roof is disrupted.

Systematic drilling, core logging, and point-load testing of drill core are useful in delineating areas where low-strength roof rock can be anticipated. This type of rock commonly occurs between coal splits where the roof of the lower bed consists of the underclay of the upper bed; it is widespread over the Pittsburgh coalbed in the Upper Ohio River Valley.

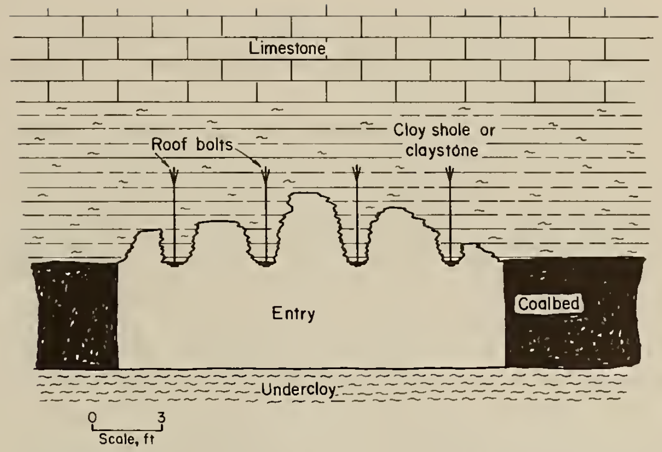

FIGURE 5. - Subtype G_2 roof failure attributed to moisture-sensitive roof rock.

Subtype G_2, Moisture Sensitivity

Moisture sensitivity is used here to indicate a significant reduction in the strength of roof rock from exposure to high humidity or water, such as is commonly found in the mine environment. (See figure 5.) The effects of moisture sensitivity consist of a progressive softening or slaking, whereby rock gradually disintegrates and eventually reverts back to a mudlike unconsolidated condition. The slaking process is one of moisture absorption, expansion, and softening. In a humid mine atmosphere, slaking may be a gradual process, the effect of which often is measured in months or years, resulting in a slow failure of roof by attrition as the dislodging of small fragments leads to larger falls of roof. The integrity of an entire mass of roof can be destroyed by this process. In mechanically supported areas, roof-bolt tension bleedoff occurs as the rock immediately against the bolt plate becomes softened, or when the anchor slips. Moisture-induced roof failure generally is most pronounced and severe near shaft bottoms and along intake air courses. The rate of roof slaking is greatest during the humid summer months when roof rock commonly is wet with condensation.

Where moisture-sensitive roof rock is thinly interbedded with moisture-stable rock, the bond between the two types of strata is weakened, leading to strata separation. Sandy roof rock rarely is affected by moisture except where the sand grains are poorly cemented and the rock reverts to a loose sand.

The principal type of moisture-sensitive roof rock in the Appalachian coal region consists of a poorly laminated lumpy claystone containing numerous slickensides, which sometimes is known as clod in miners' terminology. Generally a simple water-immersion test or exposure outdoors will determine the relative moisture sensitivity of roof rock samples and the extent to which this may become a problem underground. The prevention or control of moisture-induced roof failure can be accomplished by any of the following four principal methods:

1. Head coal.--The uppermost 4 to 6 in of coalbed, if left unmined, serves as a moisture barrier and may prevent slaking of shale roof.

2. Sealing.--Sealing entails the coating of exposed roof with an impervious layer of material to exclude moisture. The sealant can consist of an asphalt- or latex-base material with little physical strength, or it may consist of a cement-base gunite with fiber additive sprayed over a bolted wire mesh for added strength and reinforcement. The effectiveness of these measures depends largely on the quality of the sealant and the care with which it is applied. Sealing of large areas of roof invariably is a costly procedure.

3. Artificial support.--Some form of supplementary support almost always is required to reduce the failure of moisture-sensitive roof. The options are numerous and need not be discussed here. Limited experience with full-column resin bolts indicates their superior ability to hold soft, slickensided, claystone-type roof, as opposed to mechanical bolts, which lose tension as moisture attacks the rock at the bolt head and anchor. As disintegration due to moisture progresses, a larger area of roof than that immediately above the bolt plates requires support, and this usually is provided by bolted headers, straps, or mesh. Long-term disintegration usually necessitates trusses or posts and crossbars to support an increasinly large amount of deadweight from sloughing roof.

4. Air tempering.--The term "tempering" as used here refers to a modifying, adjusting, or stabilizing of mine air moisture and temperature, usually with a resulting decrease in humidity levels and humidity fluctuations. Air tempering has been accomplished through the use of water sprays, heaters, and cooling units, depending on the season, but at high cost and with limited success. A passive and more cost-effective method of tempering mine air is through the use of air-tempering rooms or entries. Here, fresh air is passed through a set of rooms or multiple entries where it is cooled and loses moisture in the humid season and, to a lesser degree, is warmed and absorbs moisture in the winter months. This eliminates large fluctuations in humidity and temperature before the air enters haulageways and other active sections of a mine. Provision must be made for some roof deterioration in the tempering rooms or entries, which should be included in the original mine design. This method of air tempering was assessed recently in both field and laboratory investigations (12). It was concluded that the use of air tempering entries may be cost effective in controlling roof disintegration, depending on conditions at a particular mine.

Subtype G_3, Bedding-Plane Spacing

A bedding plane in laminated roof strata constitutes a potential plane of separation (G_3--figure 6). The weaker the bonding along the bedding plane, the more likely a roof separation will occur as the coal underneath is removed. Weak bonding usually results from an abundance of mica flakes, clay, or coal material along the bedding plane; the more closely spaced the bedding planes or thin laminations, the more difficult it will become to form a beam of the immediate roof unless it is strongly reinforced with roof bolts. Thinly laminated roof strata of both low strength and closely spaced bedding planes, such as a "rash" of coal, claystone, and shale, are certain to be troublesome roof to support. Stackrock,

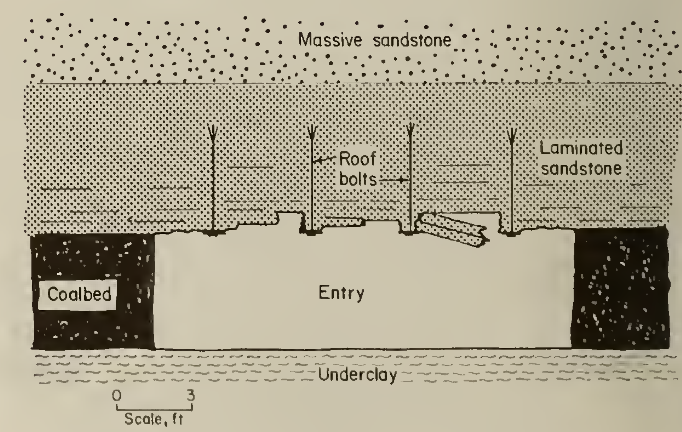

FIGURE 6. - Subtype G_3 roof failure attributed to thinly laminated strata.

a miner's term for very thinly laminated sandstone, does not respond well to conventional bolting and is prone to fall on exposure. Roof falls attributed to closely spaced and poorly bonded laminations usually occur at intersections, where the greatest span of roof is exposed, but sometimes occur randomly wherever the roof support or installation is inadequate or defective. Falls of immediate roof due to a high density of poorly bonded bedding planes tend to develop first as roof sag because the roof bolts are not anchored into overlying competent thick-bedded strata. As the strata in the immediate roof separate along bedding planes and sag, a slippage along the planes also occurs. This alone, however, is unlikely to prevent eventual roof failure unless some support is provided by longer bolts anchored in overlying competent strata. Severe sag of thinly laminated strata that does not respond to fully grouted, tensioned resin-anchored, or longer bolt calls for the use of roof trusses, posts and crossbars, or entry narrowing where feasible.

The sagging of laminated strata often results in a tension fracture along the center of the entry roof caused by the bending moment. As sagging progresses, fracturing of the roof occurs, which eventually destroys roof integrity and leads to a general disintegration and collapse.

Subtype G_4, Minor Structures

Falls of roof attributed to minor geologic structures generally are recognized by a minor structure that is exposed in the roof or fall or lies adjacent to the fall. Minor structures include virtually any geologic feature other than a normal parallel layering of roof strata. These include slickensides (fig. 7), kettlebottoms (fig. 8), clay dikes (fig. 9), paleochannels (fig. 10), joints (fig. 11), pinchouts (fig. 12), concretions (fig. 13), and faults (fig. 14). Most minor structures constitute a discontinuity in the normal beamlike structure of mine roof and thereby have a weakening effect.

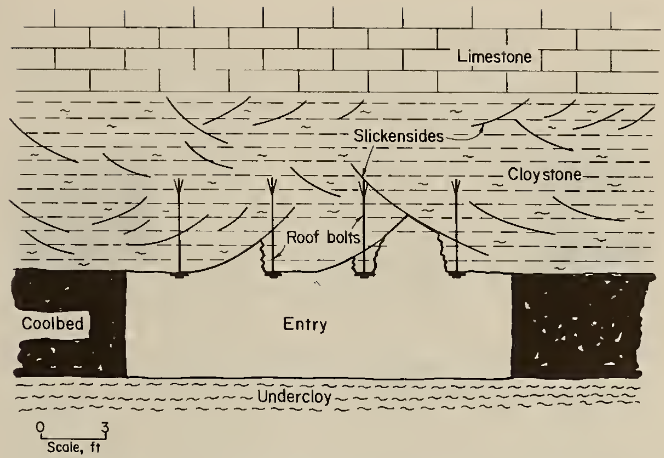

FIGURE 7. - Subtype G_4 roof failure attributed to slickensides.

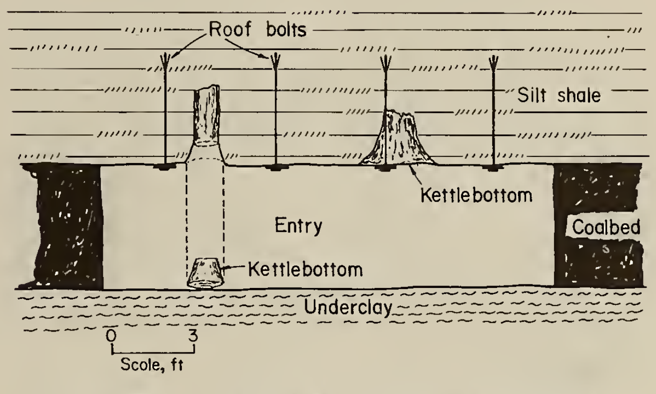

FIGURE 8. - Subtype G_4 roof failure attributed to kettlebottoms.

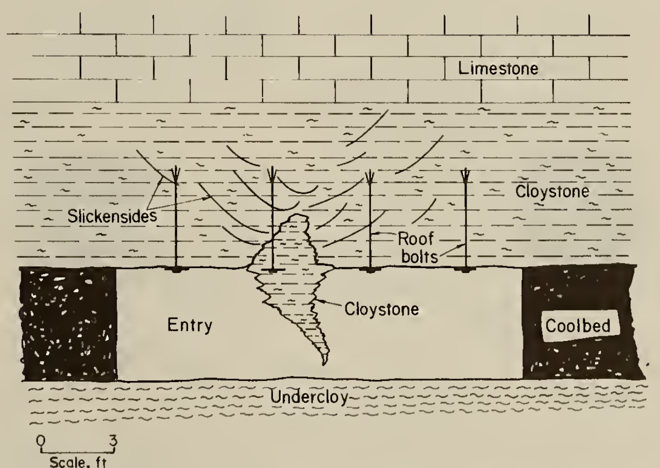

FIGURE 9. - Subtype G_4 roof failure attributed to clay vein (clay dike).

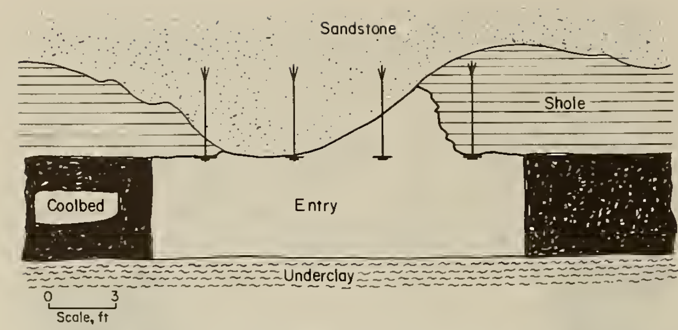

FIGURE 10. - Subtype G_4 roof failure attributed to paleochannel (roof roll).

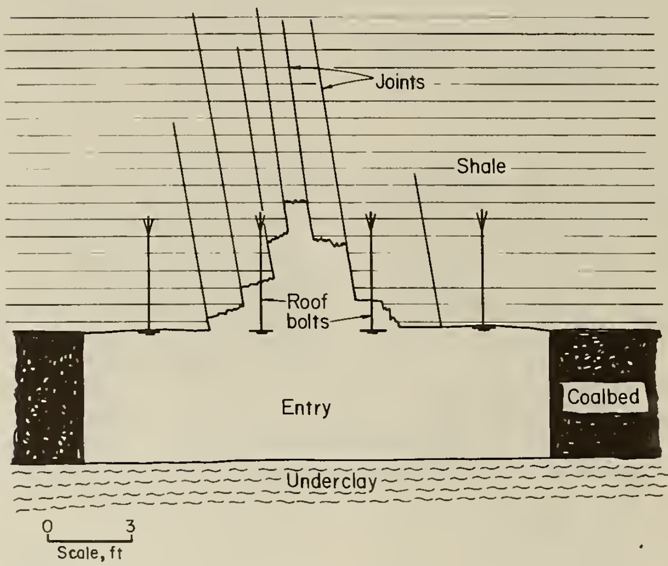

FIGURE 11. - Subtype G_4 roof failure attributed to joints.

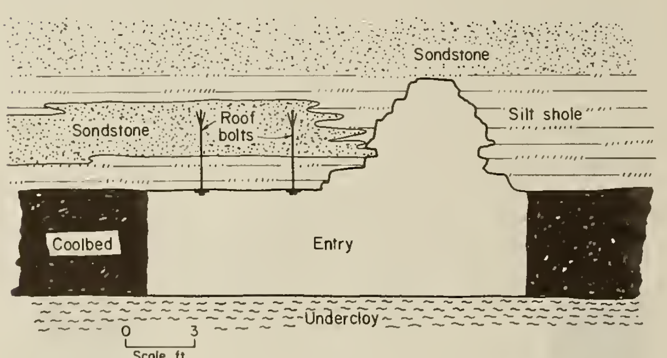

FIGURE 12. - Subtype G_4 roof failure attributed to pinchouts.

The roof rock around minor structures tends to fall soon after the supporting coal is removed and before a permanent support can be installed.

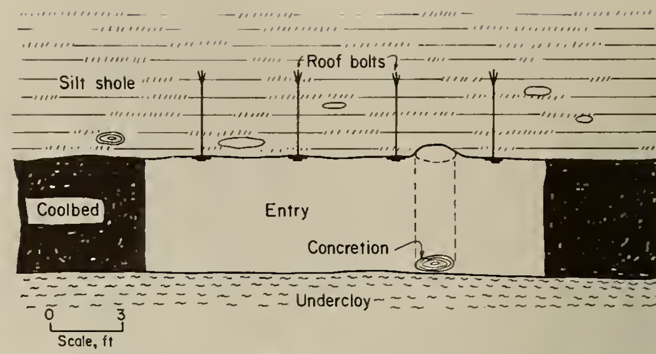

FIGURE 13. - Subtype G_4 roof failure attributed to concretions.

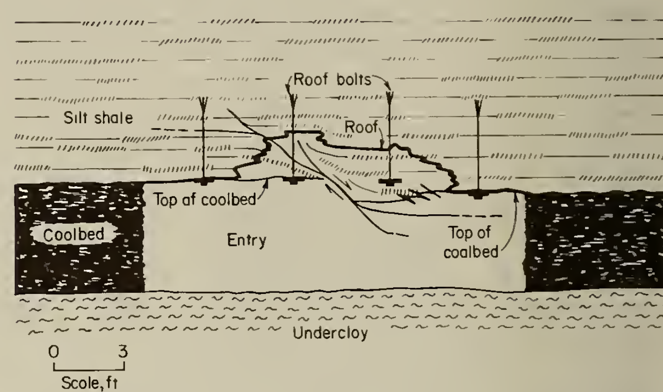

FIGURE 14. - Subtype G_4 roof failure attributed to faults.

A multitude of minor structures have been encountered in Appalachian coal mines. Few have been fully described as to identify or effect on mine roof. Virtually all are either syngenetic or diagenetic in origin; that is, they are nontectonic, having been formed contemporaneously with deposition or shortly thereafter during compaction and consolidation.

The actual character or identity of many minor structures can only be established through careful examination by an experienced geologist. The correlation between structure and roof falls, however, can be fairly readily established by a systematic mapping of roof falls and minor structures, even though the identity or trend of the structure is not always apparent.

Many minor structures such as paleochannels, clay dikes, slickensides, slumps, rolls, and horsebacks, tend toward linearity, so that directional

trends of falls soon can be established and projected. Kettlebottoms and concretions tend to occur sporadically and are particularly common in southern West Virginia.

Intraformational joints are found in virtually every mine where thick massive strata occur. They commonly will form a boundary of a roof fall but do not constitute major causative factor. However, in eastern Kentucky, the so-called hillseam, a weathered, valley stress-relief form of joint, has been the cause of numerous roof falls in drift mines. Joints are reported to play a much greater role in roof failure in the Western United States than in the Appalachian region.

It would be impractical to attempt to describe all the minor structures and their variants. However, a knowledge of the nature of each structure above the exposed roof can be vital in preventing failure by tailoring the supplementary support to the local conditions. For example, neither kettlebottoms, concretions, nor jointing in mine roof are necessarily better supported by increasing the bolt length, while pinchouts may benefit from this procedure. The support of several minor structures, such as slickensides (slips), paleochannels, and clay dikes, seem to be improved when angle bolting is employed. Resin injection and dowelling have proved effective in many instances of consolidating clay dikes in the roof. Bolted straps and headers are widely used with virtually any type of a minor structure that constitutes a discontinuity in roof strata.

The severity of failure due to minor structures can be reduced when the general directional trend of these structures can be established and entries can be turned to intersect them at a large angle as opposed to driving parallel to the structures. Every effort should be made to identify correctly the character and trend of troublesome structures on exposure, as they are not usually detectable by exploratory drilling, occur erratically, and tend to fail without warning when unexpectedly encountered during mine development.

Subtype G_5, Major Structures

This category is intended to cover the large tectonic structures such as the faults and folds that occur along the eastern limits of the Appalachian coal region, the anthracite region of eastern Pennsylvania, the Coosa and Warrior Basins of Alabama, the Illinois Basin, and some Western U.S. coal regions. Major tectonic structures, while recognized, are outside the scope of this paper and therefore are omitted from detailed discussion. However, major structures in Illinois and their effect on mine roof have been described by Nelson (13), and similar structures in Western U.S. coal regions were studied by Laird and Amundson (14).

DISCUSSION

The authors have presented a scheme for categorizing roof falls in mines based on causative factors and have indicated possible means of upgrading roof support practices to prevent their occurrence. This scheme requires some data collection regarding the pattern and character of roof falls. Each setting has its own ground control problems, which can be described as stress effects and geologic defects. These two salient conditions can occur together, but they require a somewhat different approach in terms of improved roof support. Although improper extraction or support methods can contribute to roof failure, these factors usually can be identified by the absence of geologic defects or stress effects and the close examination of operating procedures.

The proposed scheme for the diagnosis of roof falls and improvement of support clearly is only a framework in which the roof specialist of a mining company can begin to sort out his or her troubles. It is not always possible for a mine operator to allocate technical staff members full time for this kind of study.

But, if pursued conscientiously along with some sort of experimentation within the constraints of the approved roof support plan, it could contribute to accident prevention and reductions in cleanup and repair costs.

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APPENDIX.--GLOSSARY

1. Abutment pressure - In underground mining, the weight of rock above an excavation which has been transferred to the adjoining walls.

2. Angle bolts - Bolts installed in the rock over an underground opening at an angle of less than 90° from vertical (usually 45°). They usually are installed so as to penetrate a slip or shear plane and anchor over the adjacent rib (sidewall of the opening).

3. Beam effect - The result of bolting of the mine roof whereby the bolted strata behave as a single beam, stabilizing the overlying rock.

4. Bedding plane - The surface that separates each successive layer in a stratified body of rock.

5. Clay dike (clastic dike, clay vein) - Many sedimentary formations contain transecting tabular bodies of clastic material. These intruding bodies, usually called clastic dikes, are composed of extraneous materials that have invaded the containing formation along fissures either from below or above. When the invading material is composed of clay, the dikes are frequently called clay dikes or clay veins. In the Western United States, the fill material is often called "spar;" in the East, "spar" refers to a narrow clay vein occurring only near the top of the coalbed.

6. Clay stone - An indurated (hardened) clay.

7. Cleat - A system of joints in a coalbed.

8. Coal split - A coalbed that is separated by rock partings into two or more layers that may or may not rejoin some distance away. The layer of rock that separates the coal.

9. Concretion - In this report, concretions are defined as aggregates of mineral material in other sediments such as coal balls. Frequently, they have a nucleus and concentric internal structure.

10. Crib - A structure composed of frames of timber laid horizontally upon one another, as in the walls of a log cabin (used to support the roof in underground mines).

11. Crossbar (collar, cap, bridge board, roof bar) - The horizontal roof member of a timber set in mine entries. A horizontal bar supported by roof bolts.

12. Cutter - A stress-induced, steeply dipping fracture that initiates at the rib line and propagates upward into the roof rock.

13. Cutter roof - A coal mine roof that is prone to cutter-type failure.

14. Destressing - The process of relieving the pressure or load on rock around underground openings.

15. Draw slate - A weak shale in the immediate mine roof that falls when the supporting coal is removed, or soon thereafter.

16. Fault - A rock fracture of natural origin along which there has been displacement.

17. Full-column resin bolts - Roof bolts that are grouted in place in the rock and have a column of grout that extends along the entire length of the bolt. The term "resin bolt" is a misnomer, and resin refers to the type of grout; the bolt itself is type 40 steel (or better).

18. Head coal (top coal) - Coal that is left on the roof of a coal mine for the purpose of shielding the roof from the effects of exposure to mine air humidity.

19. Header - A block of wood used under the roof bolt plate to increase the effective bearing area for installed roof bolts. In some mining areas, the term refers to the block of wood placed

between the top of a post and the mine roof.

20. Horseback - In this report, it refers to rolls at the top or bottom of a coal seam. The term is sometimes applied to clastic dikes in coal, large intersecting slickensides in the roof, or fossilized tree trunks.

21. Induced stress - Rock pressure around the mine opening that has been caused by excavation of the mine itself or by other mine excavations in the vicinity.

22. In situ stress (far field stress, remnant stress) - Rock pressure that was present prior to the creation of the mine opening.

23. Joint - A fracture of natural origin that is not attended by displacement.

24. Kettlebottom (pot, bell) - Columnar masses of rock in mine roof consisting usually of the casts of ancient tree stumps. These may drop out of the roof without warning. The surface is usually highly slickensided and striated.

25. Laminations - To rock bedding in layers less than 1 in thick.

26. Lateral stress - In situ stress that is horizontal or near horizontal in orientation.

27. Layer - Any stratum of rock separated from superjacent and subjacent rock by a poorly bonded bedding plane.

28. Mesh (road mesh, wire mesh, weld mesh, chain link fence) - Interlaced or woven heavy steel wire used to help stabilize the roof and ribs of mine openings or to catch and hold rock that breaks away from the roof and ribs.

29. Multiseam mining - The mining of two or more coal seams underlying the same surface area.

30. Paleochannel - An ancient buried stream channel.

31. Pillar punching - When the load on a mine pillar exceeds the bearing strength of the underlying floor (without causing the pillar to fail), and the pillar is pushed into the floor.

32. Pillar spalling (pillar sloughing) - The breaking off of pieces of coal from the rib or pillar; the term can include minor rib failures.

33. Pinchout - The wedging out (by lateral thinning) of one layer of rock between two other layers.

34. Point-load test - A test designated to measure crushing strength of a material by using a force applied through two opposed, pointed platens (hence point load). Mathematical procedures then are used to estimate compressive strengths using point-load data.

35. Posts - Timber placed upright that are used to support the mine roof. They may be used alone with cap blocks or with headers or crossbars.

36. Pressure arch theory - The pressure arch theory states that when an opening is driven in a coalbed, the vertical load once supported by the extracted material is transferred to the sides of the opening.

37. Override (squeeze, ride over, pressure override, ride) - Downward and lateral movement of mine roof accompanied by pillar crushing, pillar punching, and roof failure, resulting from an excessive load of overburden. This condition usually develops from improper pillar extraction.

38. Parting - A thin sedimentary layer, sometimes organic, separating thicker rock or coal strata.

39. Rash - Thinly interlaminated layers of shale and coal that sometimes occur between the coalbed and the overlying rock.

40. Resin-grouted bolt - A steel bolt that is installed by using a resin to anchor the bolt in the rock prior to tensioning.

41. Roof truss - An arrangement whereby opposite-placed angle bolts are connected by a turnbuckle and thereby placed in tension, thus exerting an upward compressive force against the exposed roof.

42. Roll - A minor protrusion of rock into the top or bottom of a coalbed. Term can include small flow and compaction structures and paleochannels.

43. RQD (Rock Quality Designation) - A quantitative index, expressed as percentage, that is based on a recovery procedure for drill core. It reflects the fracturing and softening in a rock mass.

44. Sealant - Any material that is painted or sprayed onto mine roof or rib to prevent slaking or spalling. Also used on stoppings to seal off air leakage.

45. Seat earth - Stratum underlying a coal seam. Commonly a rooted clay-stone.

46. Slickenside - A polished, striated surface caused by differential compaction of coal-bearing strata.

47. Slump - The mass of sediment that has slid down from a stream bank into an open stream channel.

48. Snap top - Highly stressed coal mine roof, which under some conditions, emits audible snapping sounds soon after mining.

49. Stackrock - Thinly interlaminated shale and sandstone occurring in coal mine roofs. Individual layers in stackrock may lack lateral continuity.

50. Strap - A corrugated steel sheet (4 to 15 in wide) against the roof to assist in maintaining the stability of the roof.

51. Tension bleedoff - A decrease in the tensile prestress of point anchored, tensioned bolts that results from creep of the anchor.

52. Underclay - A bed of claystone underlying a coal seam. See "Seat earth."

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INT.-BU.OF MINES,PGH.,PA. 28248

U.S. Department of the Interior
Bureau of Mines—Prod. and Distr.
Cochrans Mill Road
P.O. Box 18070
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